AMSAT Eagle Simulator

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Background

- High Fidelity PC-Based Spacecraft C^2 Simulator developed for GPS Launch and Early Orbit, Anomaly Resolution, and Disposal Operations (LADO) Program
  - Simulate three different GPS Spacecraft Types (and their sub-types):
    - GPS II/IIA and IIF (Boeing)
    - GPS IIR/IIRM (Lockheed Martin)
  - Simulate TT&C operations through operational C^2 software
  - Simulate Space Environment
- Simulator used both for Training and event Rehearsal
  - US Air Force Space Command, 19th Space Operations Squadron (SOPS)
  - Contractor Technical Advisors and Mission Planners
- High fidelity simulator developed to satisfy Training & Rehearsal requirements with growth applications – COTS product

Simulator Architecture

- Commercial Off-The Shelf (COTS) Simulation Engine (Braxton Technologies, Inc.)
- COTS Base Models provide generic spacecraft and ground system capability
- Spacecraft-specific customization through COTS inheritance and developed modules Dynamic Link Library (DLL) – uses Microsoft Visual Studio® .net as development environment

COTS Simulation Engine (Braxton Technologies, Inc.)

- Provides the core capability to run simulations, limited only by the imagination of the developer
- Has a unique "Data Node" architecture in which information and events are passed between otherwise stand-alone modules
- Has an "Event Sequencer" to automate complex series of data node and event changes

COTS Base Models Provide Generic Spacecraft and Ground System Capability

- Air Force Satellite Control Network (AFSCN) Automated Remote Tracking Sites (ARTS)
- Orbit Propagation
- Attitude Propagation
- Communications link analysis
- Telemetry sensor base classes and failure modes
- Electronics boxes base classes and failure modes
- Electrical power and Heat Transfer "busses"
- Solar array components
- Attitude actuators (reaction wheels, magnetic torquers, etc.)
- Propulsion – solid and liquid propulsion systems

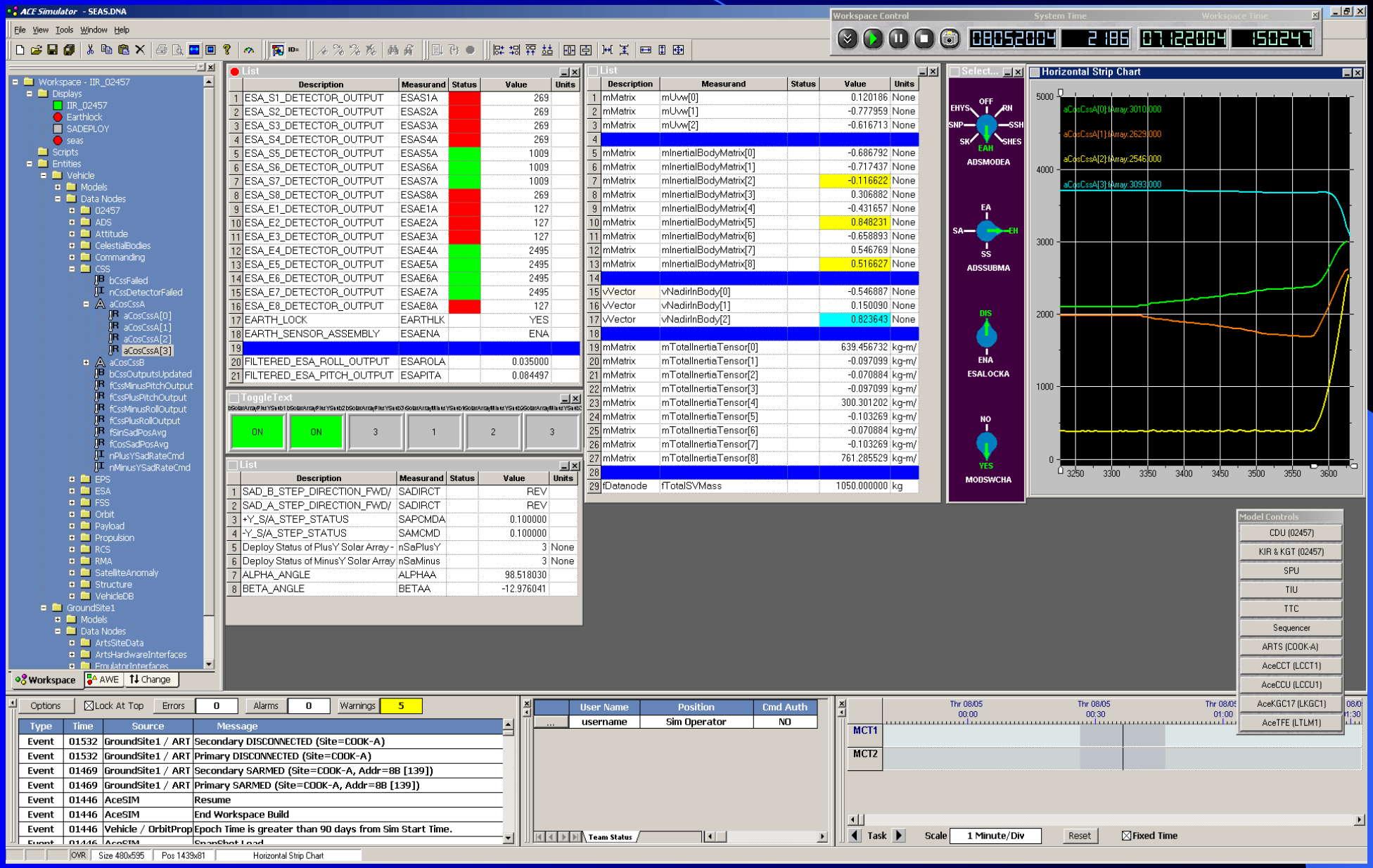
Sample COTS Modeling Details

- Orbit Propagation
  - High fidelity (Numerical integration)
    - Spherical harmonic gravity field (up to 70 x 70)
    - Lunar and Solar gravitational perturbations
    - Dynamic atmosphere models
    - Solar radiation pressure
    - Translational components of thrust
  - Medium fidelity (SGP4)
- Attitude Propagation
  - Numerical integration of net internal and external (environmental) torques
    - Mass movement or expulsion changes vehicle Inertia Tensor
    - Solar radiation pressure torques
    - Torque from Reaction Wheel accelerations
    - Torque from thrust
- Propulsion
  - Solid propellant (Apogee kick motor)
  - Liquid propellant
    - Pressurized tanks, lines, latch valves, manifolds, and thrusters
- Electrical
  - Power generation (solar)
  - Storage (batteries)
  - Distribution
- Thermal
  - Heat generated by electrical and thrust inefficiencies
  - Heat generated by resistive heating elements
  - Heat conduction between components
  - Radiative heating and cooling

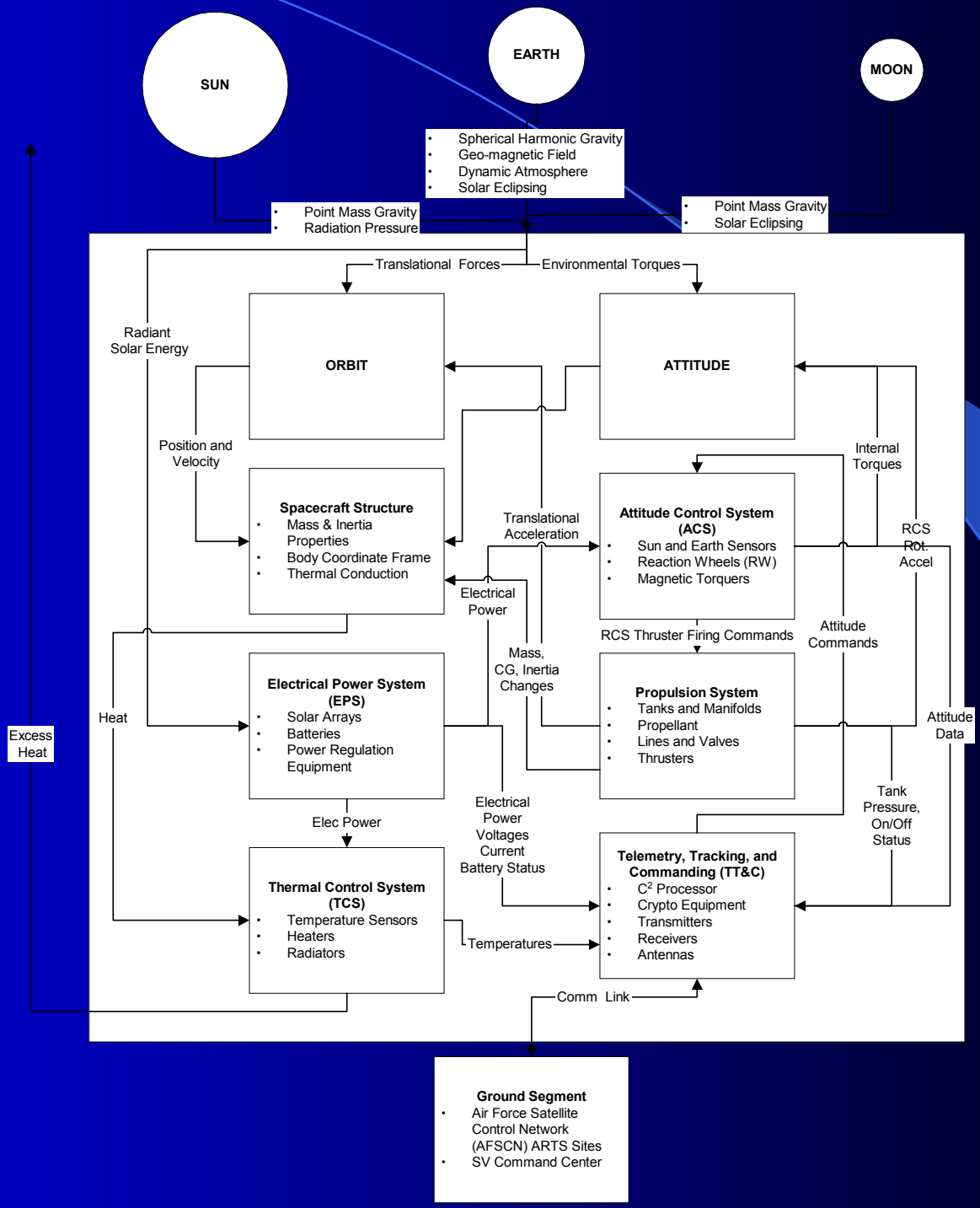
Spacecraft-Specific Customization

- COTS inheritance and developed modules Dynamic Link Library (DLL) – uses Microsoft Visual Studio® .net as development environment
  - Base component parameterization
  - Component location and orientation as applicable
  - Component-specific failures
  - Command and Telemetry mesuarands and interface with hardware
  - On-board processors
  - Attitude control logic (thruster and reaction wheel torque demands and distribution, automatic mode switching)

Simulation Engine, COTS Models, and Work Space



Simulation Architecture Block Diagram



Eagle Tailored Modules

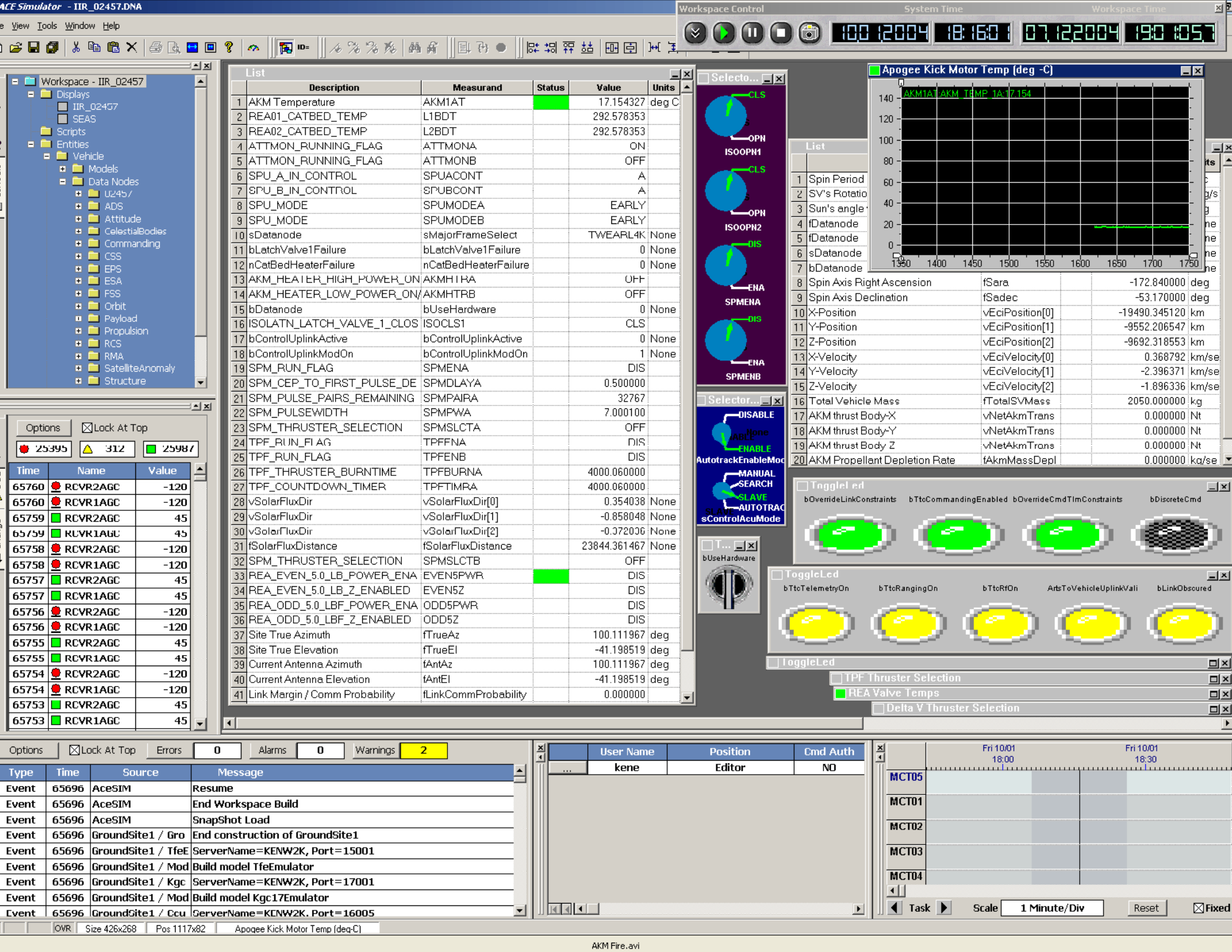
- Leverage from COTS Base Models, plus GPS-developed tailoring
  - Modify GPS spacecraft models to represent Eagle baseline
- Develop new models for AMSAT-unique equipment
  - Control Stations versus AFSCN ARTS sites
  - On-board processors
- Models for each subsystem may be developed independently
  - Subsystem teams an/or dedicated software developers
  - Central coordination required for data node interfaces between modules
- Opportunity for software developers to make contributions to Project Eagle
  - Microsoft Visual C++ .NET environment
  - Pursuing Educational Outreach
  - AMSAT EOE "policy"

Simulator Applications

- Engineering Design
  - Design validation
  - Developing / debugging control algorithms
- Spacecraft Integration
  - Hardware-in-the loop (CAN bus interfaces)
  - Simulate missing modules in partially assembled spacecraft
- Command Stations
  - Mission Planning Validation, Rehearsal, and Training
  - Anomaly Resolution (to the level of hardware modeling fidelity)
- Demonstration Tool for Promoting AMSAT
  - Potential Corporate donors
  - Attract new talent ("Wow" factor)

Making it all Happen

- Develop Giver / Receiver relationships between subsystem designer and simulator coders
  - Detailed design information required for high fidelity simulation
  - Identify interfaces to other subsystems (commands, telemetry, power, heat, etc. – to be transferred within the simulator via data nodes
- Maintain Eagle Simulator software baseline(s)
  - Develop baseline simulation
  - Develop a configuration control philosophy (including code modularization) to facilitate swapping design alternatives
- Provide Simulator access to designers and Command Stations
  - Validate design and Simulator fidelity
  - Use the Simulator as a Tool


ACE Simulator - IIR_02457.DNA
View Tools Window Help
Workspace Control
System Time
Workspace Time
Workspace - IIR_02457
Displays
IIR_02457
SEAS
Scripts
Entities
Vehicle
Models
Data Nodes
U245/
ADS
Attitude
CelestialBodies
Commanding
CSS
EPS
ESA
FSS
Orbit
Payload
Propulsion
RCS
RMA
SatelliteAnomaly
Structure
List
Description
Measurand
Status
Value
Units
AKM Temperature
REA01_CATBED_TEMP
REA02_CATBED_TEMP
ATTMON_RUNNING_FLAG
SPU_MODE
sDatanode
bLatchValve1Failure
nCatBedHeaterFailure
bDatanode
bControlUplinkActive
SPM_RUN_FLAG
SPM_CEP_TO_FIRST_PULSE_DE
SPM_PULSE_PAIRS_REMAINING
SPM_PULSEWIDTH
SPM_THRUSTER_SELECTION
TPF_RUN_FLAG
TPF_THRUSTER_BURNTIME
TPF_COUNTDOWN_TIMER
vSolarFluxDir
fSolarFluxDistance
SPM_THRUSTER_SELECTION
REA_EVEN_5.0_LB_POWER_ENA
REA_EVEN_5.0_LB_Z_ENABLED
REA_ODD_5.0_LBF_POWER_ENA
REA_ODD_5.0_LBF_Z_ENABLED
Site True Azimuth
Site True Elevation
Current Antenna Azimuth
Current Antenna Elevation
Link Margin / Comm Probability
Selecto...
CLS
OPN
ISOOPN1
ISOOPN2
DIS
ENA
SPMENA
SPMENB
Selector...
DISABLE
ENABLE
AutotrackEnableMod
MANUAL
SEARCH
SLAVE
AUTOTRAC
sControlAcuMode
T...
bUseHardware
Apogee Kick Motor Temp (deg -C)
AKM1AT.AKM_TEMP_1A:17.154
List
Spin Period
SV's Rotatio
Sun's angle
fDatanode
fDatanode
sDatanode
bDatanode
Spin Axis Right Ascension
Spin Axis Declination
X-Position
Y-Position
Z-Position
X-Velocity
Y-Velocity
Z-Velocity
Total Vehicle Mass
AKM thrust Body-X
AKM thrust Body-Y
AKM thrust Body Z
AKM Propellant Depletion Rate
ToggleLed
bOverrideLinkConstraints
bTtcCommandingEnabled
bOverrideCmdTlmConstraints
bDiscreteCmd
bTtcTelemetryOn
bTtcRangingOn
bTtcRfOn
ArtsToVehicleUplinkVali
bLinkObscured
TPF Thruster Selection
REA Valve Temps
Delta V Thruster Selection
Options
Lock At Top
25395
312
25987
Time
Name
Value
RCVR2AGC
RCVR1AGC
Errors
Alarms
Warnings
Type
Time
Source
Message
Event
AceSIM
Resume
End Workspace Build
SnapShot Load
GroundSite1 / Gro
End construction of GroundSite1
GroundSite1 / TfeE
ServerName=KENW2K, Port=15001
GroundSite1 / Mod
Build model TfeEmulator
GroundSite1 / Kgc
ServerName=KENW2K, Port=17001
Build model Kgc17Emulator
GroundSite1 / Ccu
ServerName=KENW2K, Port=16005
User Name
Position
Cmd Auth
kene
Editor
NO
Fri 10/01
18:00
18:30
MCT05
MCT01
MCT02
MCT03
MCT04
Task
Scale
1 Minute/Div
Reset
Fixed
OVR
Size 426x268
Pos 1117x82
Apogee Kick Motor Temp (deg-C)
AKM Fire.avi

Summary

- High Fidelity spacecraft simulators developed for the GPS program can be adapted for AMSAT Project Eagle and other spacecraft programs
- Develop an AMSAT-indigenous simulator developer community to work hand-in-hand with spacecraft subsystem developers or other subject matter experts
- Provide lifecycle support to the system
  - Design & development
  - Integration
  - Rehearsal an troubleshooting
- The opportunity is there for AMSAT